教育部高等教育司推荐
国外优秀信息科学与技术系列教学用书

软件工程

——理论与实践

（第二版　影印版）

SOFTWARE ENGINEERING

Theory and Practice

(Second Edition)

Shari Lawrence Pfleeger

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前　言

20 世纪末，以计算机和通信技术为代表的信息科学和技术，对世界的经济、军事、科技、教育、文化、卫生等方面的发展产生了深刻的影响，由此而兴起的信息产业已经成为世界经济发展的支柱。进入 21 世纪，各国为了加快本国的信息产业，加大了资金投入和政策扶持。

为了加快我国信息产业的进程，在我国《国民经济和社会发展第十个五年计划纲要》中，明确提出“以信息化带动工业化，发挥后发优势，实现社会生产力的跨越式发展。”信息产业的国际竞争将日趋激烈。在我国加入 WTO 后，我国信息产业将面临国外竞争对手的严峻挑战。竞争成败最终将取决于信息科学和技术人才的多少与优劣。

在 20 世纪末，我国信息产业虽然得到迅猛发展，但与国际先进国家相比，差距还很大。为了赶上并超过国际先进水平，我国必须加快信息技术人才的培养，特别要培养一大批具有国际竞争能力的高水平的信息技术人才，促进我国信息产业和国家信息化水平的全面提高。为此，教育部高等教育司根据教育部吕福源副部长的意见，在长期重视推动高等学校信息科学和技术教学的基础上，将实施超前发展战略，采取一些重要举措，加快推动高等学校的信息科学和技术等相关专业的教学工作。在大力宣传、推荐我国专家编著的面向 21 世纪和“九五”重点的信息科学和技术课程教材的基础上，在有条件的高等学校的某些信息科学和技术课程中推动使用国外优秀教材的影印版进行英语或双语教学，以缩短我国在计算机教学上与国际先进水平的差距，同时也有助于强化我国大学生的英语水平。

为了达到上述目的，在分析一些出版社已影印相关教材，一些学校已试用影印教材进行教学的基础上，教育部高等教育司组织并委托高等教育出版社开展国外优秀信息科学和技术优秀教材及其教学辅助材料的引进研究与影印出版的试点工作。为推动用影印版教材进行教学创造条件。

本次引进的系列教材的影印出版工作，是在对我国高校信息科学和技术专业的课程与美国高校的进行对比分析的基础上展开的；所影印出版的教材均由我国主要高校

的信息科学和技术专家组成的专家组，从国外近两年出版的大量最新教材中精心筛选评审通过的内容新、有影响的优秀教材；影印教材的定价原则上应与我国大学教材价格相当。

教育部高等教育司将此影印系列教材推荐给高等学校，希望有关教师选用，使用后有什么意见和建议请及时反馈。也希望有条件的出版社，根据影印教材的要求，积极参加此项工作，以便引进更多、更新、更好的外国教材和教学辅助材料。

同时，感谢国外有关出版公司对此项引进工作的配合，欢迎更多的国外公司关心并参与此项工作。

教育部高等教育司

二〇〇一年四月

From so much loving and journeying, books emerge.
Pablo Neruda

To Florence Rogart for lighting the flame;
to Norma Mertz for helping to keep it burning.

Preface

BRIDGING THE GAP BETWEEN RESEARCH AND PRACTICE

Software engineering has come a long way since 1968, when the term was first used at a NATO conference. And software itself has entered our lives in ways that few had anticipated, even a decade ago. So a firm grounding in software engineering theory and practice is essential for understanding how to build good software and for evaluating the risks and opportunities that software presents in our everyday lives. This text represents the blending of the two current software engineering worlds: that of the practitioner, whose main focus is to build high-quality products that perform useful functions, and that of the researcher, who strives to find ways to improve the quality of products and the productivity of those who build them.

Designed for an undergraduate software engineering curriculum, this book paints a pragmatic picture of software engineering research and practices. Examples speak to a student's limited experience but illustrate clearly how large software development projects progress from need to idea to reality.

The book is also suitable for a graduate course offering an introduction to software engineering concepts and practices, or for practitioners wishing to expand their knowledge of the subject. It includes examples that represent the many situations readers are likely to experience: large projects and small, object-oriented and procedural, real-time and transaction processing, development and maintenance. In particular, Chapters 12, 13, and 14 present thought-provoking material designed to interest graduate students in current research topics.

KEY FEATURES

This text has many key features that distinguish it from other books.

- Unlike other software engineering books that consider measurement a separate issue, this book blends measurement with software engineering. Measurement issues are considered as an integral part of software engineering strategy, rather than as a separate discipline. This approach shows students how to involve quantitative assessment and improvement in their daily activities. They can evaluate their progress on an individual, team, and project basis.
- Similarly, concepts such as reuse, risk management, and quality engineering are embedded in the software engineering activities that are affected by them, instead of treating them as separate issues.
- Each chapter applies its concepts to two common examples: one that represents a typical information system, and another that represents a real-time system. Both

examples are based on actual projects. The information system example describes the software needed to determine the price of advertising time for a large British television company. The real-time system is the control software for the Ariane-5 rocket; we look at the problems reported, and explore how software engineering techniques could have helped to locate and avoid some of them. Students can follow the progress of two typical projects, seeing how the various practices described in the book are merged into the technologies used to build systems.

- At the end of every chapter, the results are expressed in three ways: what the content of the chapter means for development teams, what it means for individual developers, and what it means for researchers. The student can easily review the highlights of each chapter and see the chapter's relevance to both research and practice.
- The book has an associated Web page, containing current examples from the literature, links to Web pages for relevant tool and method vendors, and a study guide for students. It is on the Web that students can find real requirements documents, designs, code, test plans, and more, so they can see real software engineering project artifacts. Students seeking additional in-depth information are pointed to reputable accessible publications and Web sites. The Web pages are updated regularly to keep the material in the textbook current and include a facility for feedback to the author and the publisher.
- The book is replete with case studies and examples from the literature. Many of the one-page case studies shown as sidebars in the book are expanded on the Web page. The student can see how the book's theoretical concepts are applied to real-life situations.
- Each chapter ends with thought-provoking questions about legal and ethical issues in software engineering. Students see software engineering in its social and political contexts. As with other sciences, software engineering decisions must be viewed in terms of the people their consequences will affect.
- Every chapter addresses both procedural and object-oriented development. In addition, a new chapter on object-oriented development explains the steps of an object-oriented development process. Using UML for common notation, each step is applied to a common example, from requirements specification through program design.
- The book has an annotated bibliography that points to many of the seminal papers in software engineering. In addition, the Web page points to annotated bibliographies and discussion groups for specialized areas, such as software reliability, fault tolerance, computer security, and more.
- The book has a solutions manual, available from Prentice Hall, as are PowerPoint slides with the figures, tables, and sample instructional slides.
- Each chapter includes a description of a term project, involving development of software for a mortgage processing system. The instructor may use this term project, or a variation of it, in class assignments.
- Each chapter ends with a list of key references for the concepts in the chapter, enabling students to find in-depth information about particular tools and methods discussed in the chapter.

CONTENTS AND ORGANIZATION

This text is organized in three parts. The first part (Chapters 1 to 3) motivates the reader, explaining why knowledge of software engineering is important to practitioners and researchers alike. Part I also discusses the need for understanding process issues and for doing careful project planning. Part II (Chapters 4 to 11) walks through the major steps of development and maintenance, regardless of the process model used to build the software: eliciting and checking the requirements, designing a solution to the problem, writing and testing the code, and turning it over to the customer. Part III (Chapters 12 to 14) focuses on evaluation and improvement. It looks at how we can assess the quality of our processes and products, and how to take steps to improve them.

Chapter 1: Why Software Engineering?

In this chapter we address our track record, motivating the reader and highlighting where in later chapters certain key issues are examined. In particular, we look at Wasserman's key factors that help define software engineering: abstraction, analysis and design methods and notations, modularity and architecture, software life cycle and press, reuse, measurement, tools and integrated environments, and user interface and prototyping. We discuss the difference between computer science and software engineering, explaining some of the major types of problems that can be encountered, and laying the groundwork for the rest of the book. We also explore the need to take a systems approach to building software, and we introduce the two common examples that will be used in every chapter. We also introduce the context for the term project.

Chapter 2: Modeling the Process and Life Cycle

In this chapter, we present an overview of different types of process and life-cycle models, including the waterfall model, the V-model, the spiral model, and various prototyping models. We also describe several modeling techniques and tools, including systems dynamics, SADT, and other commonly-used approaches. Each of the two common examples is modeled in part with some of the techniques introduced here.

Chapter 3: Planning and Managing the Project

Here, we look at project planning and scheduling. We introduce notions such as activities and milestones, work breakdown structure, activity graphs, risk management, and costs and cost estimation. Estimation models are used to estimate the cost and schedule of the two common examples. We focus on actual case studies, including management of software development for the F-16 airplane and for Digital's alpha AXP programs.

Chapter 4: Capturing the Requirements

In this chapter, we look at requirements analysis and specification. We explain the difference between functional and nonfunctional requirements, present several ways to

describe different kinds of requirements, and discuss how to prototype requirements. We see how several types of formal methods can be used in specifying and evaluating requirements. Other topics discussed include requirements documentation, requirements reviews, requirements quality and how to measure it, requirements testability, and how to select a specification method. The chapter ends with application of some of the methods to the two common examples.

Chapter 5: Designing the System

This chapter focuses on architectural issues, and we begin by discussing Shaw and Garlan's framework for software architecture. Next, we describe the difference between the conceptual design and the technical design. We discuss the roles of the personnel who perform the design and describe two basic approaches to design: composition and decomposition. Then, we identify characteristics of good design, introduce several design strategies, and give examples of several system design techniques and tools. It is in this chapter that the reader learns about client-server architecture, reusable design components, human-computer interface design, design for secure and reliable systems (including error handling and fault tolerance), design patterns, formal design methods, and how to assess design trade-offs. After explaining how to evaluate and validate the quality of a design, and how to document the results, we turn to issues of program design.

Program design guidelines are explained, including top-down versus bottom-up, modularity and independence, and the difference between logical and physical design. We look at design for concurrency and for safety-critical systems, and we examine the design flaws that led to the Therac-25 malfunctions. We describe several design tools, and there is a thorough discussion of design quality and how to measure it. The chapter introduces design reuse, reviews, and inspections and explains the need to document design rationale. Finally, the chapter ends with examples of design for the information system and real-time examples.

Chapter 6: Concerning Objects

Chapter 6 takes a detour to consider the special properties of object-oriented development. We begin by describing use case scenarios, discussing how to capture objects and their characteristics from the natural language requirements. Next, we examine system design, to see how to generate the high-level information needed to find a solution. We then enrich the system design, adding nonfunctional requirements and details required in the program design. Employing UML and its constructs, we generate an object-oriented specification and design for a common example, the Royal Service Station.

Taking a careful look at object-oriented measurement, we apply some of the common object-oriented metrics to the service station example. We note how to use changes in the metrics to help us decide how to allocate resources and search for faults. Finally, we apply object-oriented concepts to our information systems and real-time examples.

Chapter 7: Writing the Programs

In this chapter, we address issues in implementing the design to produce high-quality code. We discuss standards and procedures and suggest some simple programming guidelines. Examples are provided in a variety of languages, including both object-oriented and procedural. There are thorough discussions of the need for program documentation and an error-handling strategy, and the chapter ends by applying some of the concepts to the two common examples.

Chapter 8: Testing the Programs

In this chapter, we explore several aspects of testing programs. We distinguish conventional testing approaches from the cleanroom method, and we look at how to test a variety of systems. We present definitions and categories of software problems, and we discuss how orthogonal defect classification can make data collection and analysis more effective. We then explain the difference between unit testing and integration testing. After introducing several automated test tools and techniques, we explain the need for a testing life cycle and how the tools can be integrated into it. Finally, the chapter applies these concepts to the two common examples.

Chapter 9: Testing the System

We begin with principles of system testing, including reuse of test suites and data, and the need for careful configuration management. Concepts introduced include function testing, performance testing, acceptance testing, and installation testing. We look at the special needs of testing object-oriented systems. Several test tools are described, and the roles of test team members are discussed. Next, we introduce the reader to software reliability modeling, and issues of reliability, maintainability, and availability are discussed. The reader learns how to use the results of testing to estimate the likely characteristics of the delivered product. The several types of test documentation are introduced, too, and the chapter ends by describing the test strategies of the two common examples.

Chapter 10: Delivering the System

This chapter discusses the need for training and documentation and presents several examples of training and documents that could accompany the information system and real-time examples.

Chapter 11: Maintaining the System

In this chapter, we address the results of system change. We explain how changes can occur during the system's life cycle, and how system design, code, test process, and documentation must accommodate them. Typical maintenance problems are discussed, as well as the need for careful configuration management. There is a thorough discussion

of the use of measurement to predict likely changes, and to evaluate the effects of change. We look at reengineering and restructuring in the overall context of rejuvenating legacy systems. Finally, the two common examples are evaluated in terms of the likelihood of change.

Chapter 12: Evaluating Products, Processes, and Resources

Since many software engineering decisions involve the incorporation and integration of existing components, this chapter addresses ways to evaluate processes and products. It discusses the need for empirical evaluation and gives several examples to show how measurement can be used to establish a baseline for quality and productivity. We look at several quality models, how to evaluate systems for reusability, how to perform postmortems, and how to understand return on investment in information technology. These concepts are applied to the two common examples.

Chapter 13: Improving Predictions, Products, Processes, and Resources

This chapter builds on Chapter 11 by showing how prediction, product, process, and resource improvement can be accomplished. It contains several in-depth case studies to show how prediction models, inspection techniques, and other aspects of software engineering can be understood and improved using a variety of investigative techniques. This chapter ends with a set of guidelines for evaluating current situations and identifying opportunities for improvement.

Chapter 14: The Future of Software Engineering

In this final chapter, we look at several open issues in software engineering. We revisit Wasserman's concepts to see how well we are doing as a discipline. In addition, we examine several issues in technology transfer and decision-making to determine if we do a good job at moving important ideas from research to practice.

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Shari Lawrence Pfleeger
Washington, DC

About the Author

Shari Lawrence Pfleeger is president of Systems/Software, Inc., a consultancy specializing in software engineering and technology. In the past, she has been a member of the University of Maryland's Computer Science Department, founder and director of Howard University's Center for Research in Evaluating Software Technology (CREST), a visiting scientist at the City University (London) Centre for Software Reliability, principal scientist at MITRE Corporation's Software Engineering Center, and manager of the measurement program at the Contel Technology Center. Thus, she has experience both with the practical problems of software development and the theoretical underpinnings of software engineering and computer science. Pfleeger is well-known for her work in empirical studies of software engineering.

Dr. Pfleeger has been associate editor-in-chief of *IEEE Software*, where she edited the Quality Time column. She is currently associate editor of *IEEE Transactions on Software Engineering*. A member of IEEE, the IEEE Computer Society, and the Association for Computing Machinery, Pfleeger has twice been on the executive committee of the Technical Council on Software Engineering. She was the general chair of the Second International Symposium on Software Metrics (in London, England), the program co-chair of the Fourth International Symposium on software Metrics (in Albuquerque, New Mexico), and the co-chair of the Fifth Workshop on Empirical Studies of Software Engineering (Bethesda, Maryland).

Dr. Pfleeger is the author of many books and articles; she has been named repeatedly by the *Journal of Systems and Software* as one of the world's top software engineering researchers. Among her books are *Introduction to Discrete Structures* (with David Straight; Wiley, 1985), *Software Engineering: The Production of Quality Software* (Macmillan, 1987 and 1991), *Software Metrics: A Rigorous and Practical Approach* (with Norman Fenton; PWS Publishing, 1997) and *Applying Software Metrics* (with Paul Oman; IEEE Computer Society Press, 1997).

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